# Mixed Layer Revolution and Mesoscale Variability in the Laborator Sea

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## LONG TERM GOALS

Our long-term goal is to understand the effects of mesoscale variability on upper ocean processes.

## OBJECTIVES

Our objective is to understand how mesoscale variability (primarily due to eddies) affects both the depth and character of convection as well as the subsequent restratification of upper ocean waters in the Labrador Sea. We want to understand the links between the evolution of the surface mixed layer, changes in the heat content, and the turbulent heat fluxes in the water column before, during, and after deep convection.

## APPROACH

We used acoustically tracked, neutrally buoyant RAFOS floats to "tag" and follow water in the Labrador Sea. The floats obtain three navigation fixes per day from four moored sound sources, allowing us to explore Lagrangian pathways and mesoscale variability. During the convection season, between 150-200 temperature ($T$, to 0.001 $^{o}$C resolution) and pressure ($P$, to 0.5 dbar) measurements are collected each day. Knowing the depth response of the float to vertical water velocity ($w$), we can determine the vertical velocity of the water from the float's pressure record. Combining precise temperature data with these velocities allows us to estimate the turbulent heat flux $<w'T'>$. In addition, we have modified the floats by adding a 30 cm$^3$ ***vo****lume* *cha*nging (vocha) mechanism. This vocha is capable of changing the density of the float by about 2 kg m$^{-3}$ at discrete 0.15 kg m$^{-3}$ intervals. We have used this capability by sending the float on repeated profiles of the water column collecting $T$ and $P$, allowing us to monitor the evolution of the mixed layer depth and heat content. It is important to realize that these measurements are being made in a Lagrangian framework, moving with the water. Difficulties accounting for heat budgets from a fixed, stationary position are thus avoided.

## WORK COMPLETED

The four sound sources used for float navigation and four convection RAFOS floats were deployed from the C.S.S. Hudson in the fall of 1996. During the winter 1997 cruise of the R/V Knorr an additional 18 floats were launched, with 9 more from the spring 1997 cruise of the C.S.S. Hudson. We did, however suffer an unexpectedly large failure rate; out of the 31 floats

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launched, 14 were not heard from again or returned no useful data. An additional 14 floats surfaced prematurely as a fail-safe response to the float's central processing computer locking-up. After implementing repairs for the above problem and deploying 23 additional float from the January 1998 cruise on the R/V Knorr, we unfortunately uncovered yet another problem. Due to a modification in the float software made prior to this experiment, all the float data from the 1998 convection season was garbled in an irrecoverable manner before transmission.

In spite of our difficulties, we did obtain 60 vertical profiles to almost 1000-m depth, 11 float-months of subsurface Lagrangian trajectories, and over 400 5-hour *T/P* time-series. We were only able to produce float displacement vectors for the winter 1998 deployment. The acoustic navigation worked very well, even in the wind-roughened, surface-trapped sound channel found in the Labrador Sea winter.

Three of the four sound sources have been recovered (from three different ships!) during the summer of 1998. The fourth still remains operational, and will be recovered as the opportunity arises.

## RESULTS

The RAFOS floats have monitored mixed layer cooling prior to convection during the fall of 1996 where the 100 m deep mixed layer cooled by 1 $^{o}$C in 30 days, indicating a surface heat flux of 150 W m$^{-2}$. During the early convection season (mid-February to early March, 1997), we monitored the mixed layer deepening from 600 m to in excess of 1000 m (the maximum extent of our instrument). The change in water column heat content over these 20 days indicates a heat flux of 340 W m$^{-2}$. At this same time, we also observed downward vertical velocities of nearly near 8 cm s$^{-1}$. Preliminary correlations with temperature perturbations give turbulent heat fluxes around 150 W m$^{-2}$, but more analysis is required to improve these estimates. Finally, floats deployed in and near the West Greenland Current show eddies, both cyclonic and anticyclonic, being formed and advected around the edge of the basin. One float experienced over 20 revolutions in such an eddy. The relative vorticity of this eddy was 0.3 to 0.4 times that of the coriolis parameter *f*.

Despite numerous problems, we have demonstrated the capability of the modified RAFOS float to measure changes of heat content of the mixed layer, and we are able to use the *T* and *P* time-series data to estimate turbulent heat fluxes.

## IMPACT/APPLICATIONS

We consider the profiling RAFOS float to be an effective tool for the monitoring the evolution of the surface waters in a Lagrangian framework. The float, with minimal changes in hardware and software, can also monitor obduction/subduction of thermocline waters before/after the winter cooling season.

## TRANSITIONS

No technology transfers or transitions were accomplished this year pertaining to this project.

## RELATED PROJECTS

RAFOS floats are currently being deployed as part of the Atlantic Climate Change Experiment (ACCE) in the extension region of the North Atlantic Current (NAC). Our goals in this project are (i) to explore the structure of the boundary between the subpolar and subtropical gyres, and (ii) the sites and mechanisms of exchange. The floats used are isopycnal, and measure temperature, pressure, and oxygen for their nearly two-year missions. One sound source deployed as part of the deep convection experiment in the Labrador Sea provides acoustic navigation in the western subpolar basin. We anticipate that some floats deployed in the ACCE program may be entrained by the Irminger or Greenland Currents and thus map out warm-water pathways into the Labrador Sea.